

# DETECTION OF AN INTERSTELLAR FLUX OF GAMMA RAYS

ALBERT E. METZGER

Jet Propulsion Laboratory, California Institute of Technology, Pasadena

ERNEST C. ANDERSON and MARVIN A. VAN DILLA

Los Alamos Scientific Laboratory  
University of California, Los Alamos, New Mexico

JAMES R. ARNOLD

Chemistry Department, University of California at San Diego, La Jolla

The intensity and energy distribution of radiation produced by astrophysical processes is important to an understanding of stellar evolution and the mechanism of cosmic ray production and acceleration. Previous efforts to detect a gamma ray flux have been confined to balloon and rocket flights, close to extraneous sources of radiation in the atmosphere and the radiation belts. Although measureable fluxes have been observed in such experiments, only gamma ray fluxes accompanying solar flares have been identified as extraterrestrial in origin.<sup>1</sup> In this paper, we report gamma ray measurements at distances of  $7 \times 10^4$  km to  $4 \times 10^5$  km from the Earth, far enough to make contributions from the Earth negligible. The experiment involved operation of a spectrometer on two flights of the Ranger spacecraft with the primary purpose of monitoring surface radiation from the Moon. Data obtained in cislunar space points to the detection of a substantial interstellar flux of gamma rays.

The scintillation spectrometer consisted of a 2-3/4" beveled CsI (Tl) scintillation crystal, with a plastic scintillator phoswich for the rejection of charged particles.<sup>2</sup> The mass surrounding the inorganic

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scintillator crystal has a mean value of approximately  $2.5 \text{ gm/cm}^2$ , the half-thickness for radiation of 60 Kev. Output pulses from the phototube were amplified and analyzed in a kicksorter of 32 channels, the last of which counted all pulses above a given level. The detector system was housed in a thin aluminum shell at the end of an extensible six foot boom. The boom was provided to reduce the background of spacecraft-generated secondary gamma rays, and was programmed to extend after twelve hours of operation in a stowed position. Data transmission from the earlier flight spanned a period of 40 hours; five hours of data were received from the second flight with the boom in the stowed position only. The combined energy spectra of the two flights cover a range of 70 Kev to 4.4 Mev.

An initial report on the flux observed between 0.4 and 2 Mev on the earlier flight has appeared previously.<sup>3</sup> The data from this flight has been refined and extended to include the full energy range scanned, as well as the stowed position mode of operation. The contributions from calibration sources of  $\text{Co}^{57}$  and  $\text{Hg}^{203}$ , and of two extraneous radiation sources have been removed. Data from the second flight has been similarly reduced. In the second flight, the spacecraft was passing through the fringe of the outer radiation belt when the spectrometer began to operate. Therefore, only data received during the last hour of flight, when the reproducibility of successive readouts indicate that the belts had been passed, is considered here.

The observed fluxes from Ranger 3 with the detector stowed and

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extended, and Ranger 5 stowed are shown in Figure 1. Extension of the boom reduces the contribution of cosmic ray induced secondary counts by a geometrical factor of 13. Figure 1 shows that the actual reduction was much less. From this it is deduced that the contribution of the interstellar flux predominates in the extended position.

The spectra of the two flights in the stowed position are seen to be in reasonably good agreement, although the absolute values differ by about 20%. This difference may or may not be significant.

The upper channels of the Ranger 3 extended spectrum appear high since the relative proportion of secondary gamma rays at high energy is not expected to decrease abruptly above 1 Mev. These count rates were also accompanied by an anomalously high count rate in the overflow channel which appears to have been due to a partial malfunction in the instrument. The continuum response varies roughly as  $E^{-1.3}$  for the extended spectra and  $E^{-0.9}$  for the stowed. The instrumental response has not yet been unfolded.

Small peaks at 0.51 Mev in both stowed spectra can be attributed to secondary production. The absence of peaks at 0.51 Mev in the extended position, and at 2.23 Mev in the stowed position of both Ranger 3 and Ranger 5, sets upper limits for these lines which are generated by pair production and neutron-proton reactions respectively. Based on the Ranger 3 data where long periods of stable performance were measured, these become  $0.014 \gamma/\text{cm}^2 \text{ sec}$  for the 0.51 Mev line and  $0.005 \gamma/\text{cm}^2 \text{ sec}$  for the 2.23 Mev line.

The integrated fluxes observed are 3.1 counts/cm<sup>2</sup> sec for 0.09-4.3 Mev on Ranger 5, 3.2 counts/cm<sup>2</sup> sec for 0.12-2.5 Mev on Ranger 3 (detector stowed), and 3.1 counts/cm<sup>2</sup> sec between 0.07 and 1.2 Mev on Ranger 3 (detector extended).

The Sun has been eliminated as the source of the observed flux by the lack of any significant change in count rate response after the Ranger 3 spacecraft performed an orientation maneuver which carried the detector through an angle of 145° with respect to the Sun. Laboratory tests have shown that the detector possesses sufficient anisotropy of response to have produced detectable changes in count rates at the low energy end if 25% or more of the flux were solar in origin.

The primary gamma ray flux detected in these experiments is evidently an interstellar flux because of 1) the distance of the instrument from the Earth and the constancy of count rate with change in distance once the radiation belts are left behind, 2) the comparatively small reduction in counting rate with extension of the detector from the spacecraft, much less than if this were entirely the result of cosmic ray secondary production and 3) the ability to eliminate the sun as the prime source.

The intensity of the flux makes a synchrotron origin very unlikely, while the absence of a line at 0.51 Mev makes it unlikely that the flux has been produced by nuclear interactions of high energy particles. The mechanisms of bremsstrahlung and inverse Compton scattering which have been suggested recently are more promising.<sup>4</sup>

Extrapolation of these results to the mean energy of the X-ray

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flux detected in rocket flights<sup>5</sup> indicates a general agreement. If the agreement is meaningful, certain mechanisms for the production of this X-ray flux such as line transitions and synchrotron emission can be eliminated.

### Figure Caption

Figure 1 Energy spectra obtained in cislunar space by the gamma ray spectrometers on Ranger 3 and Ranger 5.

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# RANGER 3&5 GAMMA RAY FLUX

(Co<sup>60</sup> & K<sup>40</sup> REMOVED)

Ranger 3 - detector stowed  
 ■ HIGH GAIN    □ LOW GAIN

Ranger 3 - detector extended  
 ▲ HIGH GAIN    △ LOW GAIN

Ranger 5 - detector stowed  
 ● HIGH GAIN    ○ LOW GAIN

COUNTS/cm<sup>2</sup> · sec. (MEV)

GAMMA RAY FLUX

